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An Inexpensive Portable Desktop Flight Simulation Task

By

John S. Crowley
John A. Caldwell
J. Lynn Caldwell
Scott Earheart
Cindy Tibbetts

Aircrew Health and Performance Division

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U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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LTC, MS
Director, Aircrew Health and
Performance Division

JOHN A. CALDWELL, Ph.D.
Chairman, Scientific
Review Committee

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A modified recreational flight simulation was tested as part of two recent studies examining the effects of Dexedrine on sleep deprived aviators. Software and controls for this task cost under $250. Six male and five female UH-60 pilots were sleep deprived for 40 hours twice in a double-blind repeated measures study comparing 10 mg Dexedrine (x3 doses) to placebo. Every 4 hours, subjects flew the profile and were scored on their speed and accuracy of flying a simulated light fixed-wing aircraft through 22 gates under varying wind conditions. In the males, a drug x session interaction ($p=0.0361$) was due to variability with placebo but not Dexedrine. An auditory reaction time secondary task was added to the female pilots' workload resulting in a consistent (but not statistically significant) trend toward worse performance in the placebo condition. The drawbacks of this crude measure of flight performance must be weighed against the costs and feasibility of high fidelity flight simulation or in-flight research. Detailed task design specifications are provided.

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Introduction

The defining characteristic of aviators is that they fly. Therefore, those wishing to study aviator performance are sooner or later compelled to measure flying skill or ability. This can be accomplished in a number of ways, ranging from the most basic laboratory task to actual combat missions. Each of these has advantages and disadvantages that may cause a researcher to favor one over another, depending on the research question and available resources (table 1). In general, it is fair to say that simpler cognitive tasks are easier to control but bear less resemblance to actual flying, while performance measures involving actual flight can be very expensive to collect and complicated to analyze.

Table 1.
Methods of measuring flight performance and their suitability.

Performance measure	Examples	Sensitivity, experimenter control	External validity, realism, cost
single cognitive test	reaction time, serial add/ subtract	more	less
combined cognitive tests	SYNWORK, MATS-B		
low fidelity flight simulation	part-task cockpit trainer		
high fidelity flight simulation	motion-based simulator with visual displays		
research aircraft and crew	research aircraft flies specified flight profile	less	more
operational aircraft and crew	operational aircraft flies real mission		

Since flying ability can be measured under tightly controlled experimental conditions, many researchers view flight simulation as a useful compromise between scientific rigor and realism. However, full mission flight simulators are not widely available to researchers and can be almost as difficult and expensive to manage as actual aircraft. Flight simulators are generally fixed-base facilities (i.e., cannot be moved), which may be a severe limitation. In the end, the measurement of flight performance is often sacrificed for reasons of cost, facilities, or the formidable logistical headaches associated with this equipment. This may be unacceptable in today's aviation research environment, as the customer may expect to see at least some aspect of flight performance measured in his/her research program.

There is a need for an inexpensive, portable tool that is a sensitive measure of flight performance. Ideally, this tool would be easy to learn, well-suited for deployment studies, and easy to interpret. This report describes our effort to develop such a tool.

To this end, time was made available in two ongoing studies involving sleep deprivation and the stimulant dextroamphetamine at the U.S. Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama (Caldwell et al., 1994; Caldwell et al., 1995). This allowed the collection of data from degraded aviator/subjects who were simultaneously being tested in a full mission helicopter simulator. The desktop flight simulation (DTFS) task is composed of commercially available flight simulation software and hardware costing less than $250.

General methodology

These two studies involved a 40-hour sleep deprivation paradigm and a repeated-measures, double-blind design with three doses of either dextroamphetamine (10 mg) or placebo administered at regular intervals (figure 1). Informed consent was obtained from all subjects and a physical examination was conducted prior to enrollment in the study (Caldwell et al., 1994).

Throughout the week, performance was frequently assessed using a variety of measures, including flight performance in a fully-instrumented UH-60 Black Hawk helicopter flight simulator, cognitive testing, and electroencephalography (EEG). The two studies were identical in every respect, except that they involved males and females, respectively. The general methodology is described in figure 1. Full details are contained in Caldwell et al. (1994), and Caldwell et al. (1995). These studies provided a known stressor (sleep deprivation) and an effective countermeasure (dextroamphetamine) to assess the sensitivity of the novel task.

DTFS

A commercially available personal computer (PC)-based flight simulation program (Microsoft Flight Simulator 4.0® [FS 4.0®]*), combined with a custom-designed timed flight course (Microsoft Aircraft and Scenery Designer®)*, served as the basis for the task. In these studies, the task was run on an IBM-compatible 486-66 MHz computer equipped with VGA graphics and a 17-inch cathode ray tube (CRT).

Flight control was via a realistic flight yoke (CH Products Virtual Pilot®)*, with system interface using either mouse or keyboard, according to individual subject preference (for tasks such as raising the landing gear). The timed course consisted of 22 gates positioned at various altitudes and headings (figure 2 and appendix B), through which the subject flew a simulated Cessna 182 aircraft (figures 3 and 4). The aircraft was positioned at the beginning of the course. Turbulence and winds (from varying directions) were present at certain preset altitudes (table 2).

Assuming a stable flight path between gates, these environmental settings resulted in windy conditions between gates 16 and 21. The aircraft was preset by the technician to a slightly out-of-trim condition to prevent 'hands-off' flying. The complete instructions read to the subject are provided as appendices C and D.

Table 2.
Flight profile wind settings.

Altitude block	Direction	Velocity
4800-5199	90	20
5200-5399	180	20
5400-5599	270	20

*See manufacturer's list at appendix A.

TIME	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
00-01				DEX/PBO		DEX/PBO	
01-02				simulator		simulator	
02-03				eeg		eeg	
03-04		sleep	sleep	minisim poms	sleep	minisim poms	sleep
04-05				DEX/PBO		DEX/PBO	
05-06				simulator		simulator	
06-07				eeg		eeg	
07-08		wake up	wake up	minisim poms	wake up	minisim poms	wake up breakfast RELEASE
08-09		testdose breakfast	breakfast	DEX/PBO breakfast	breakfast	DEX/PBO breakfast	
09-10		simulator	simulator	simulator	simulator	simulator	
10-11		eeg	eeg	eeg	eeg	eeg	
11-12		minisim	minisim poms	minisim poms	minisim poms	minisim poms	
12-13		poms	lunch	lunch	lunch	lunch	
13-14		lunch simulator	simulator	simulator	simulator	simulator	
14-15		eeg	eeg	eeg	eeg	eeg	
15-16		minisim	minisim poms	minisim poms	minisim poms	minisim poms	
16-17		poms					
17-18		simulator	simulator	simulator	simulator	simulator	
18-19	ARRIVE med exam	eeg	eeg	eeg	eeg	eeg	
19-20		minisim poms	minisim poms	minisim poms	minisim poms	minisim poms	
20-21	eeg hookup						
21-22		dinner pt	dinner pt	dinner pt	dinner pt	dinner pt	
22-23	freetime	shower poms	shower	shower poms	shower	shower poms	
23-24	bed time	bed time	poms	bed time	poms	bed time	

Note: DEX = Dexedrine dose (10 mg), PBO = Placebo

Figure 1. Overall testing schedule in which the DTFS task is represented by "minisim."

Secondary task

In experiment 2, a secondary auditory reaction time task was added. Every 10 seconds, a speaker behind the computer monitor emitted either a low (550 hz) or a high frequency tone (600 hz) of 0.1 second duration. Subjects were instructed to press the red button on the right yoke handgrip (figure 3) upon hearing the lower-pitched tone. Low tones occurred with a 40 percent probability. The task was controlled by a Coulbourn Instruments®* electronic timer.

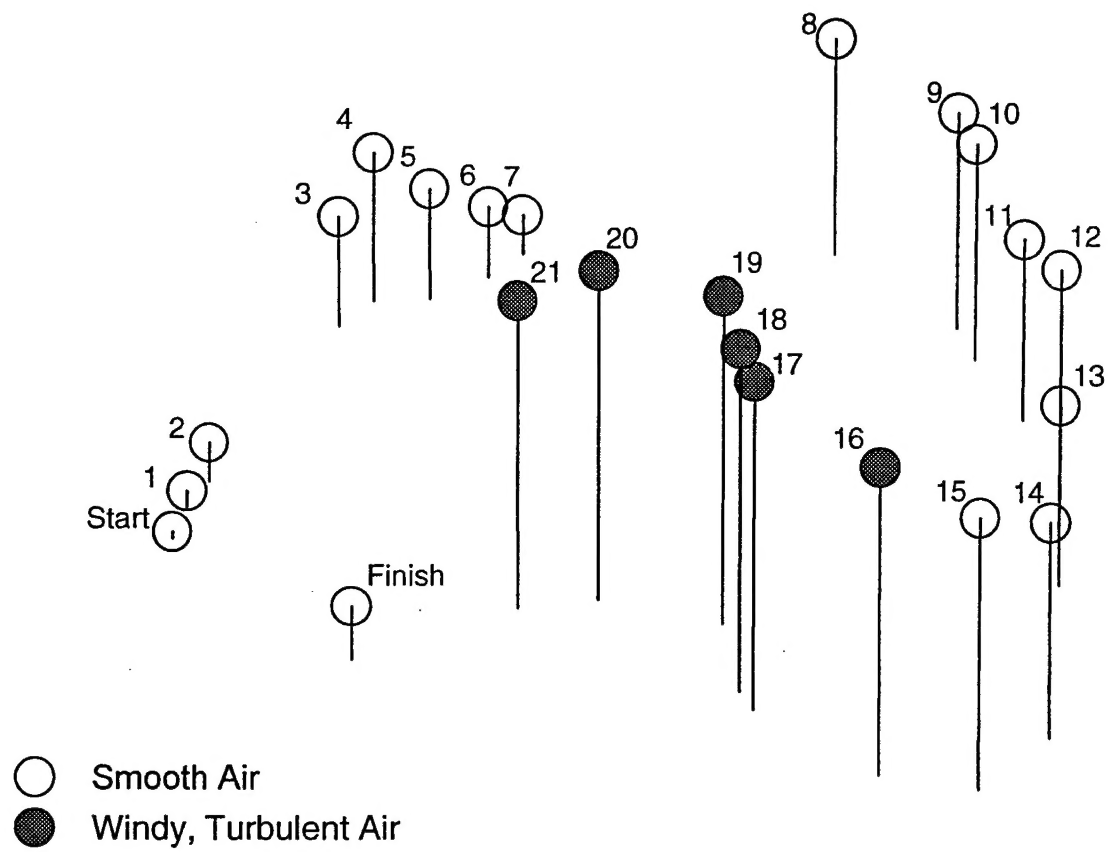

Figure 2. 3D plot of 25-minute 22-gate flight profile

Figure 3. The DTFS screen and the Virtual Pilot® yoke.

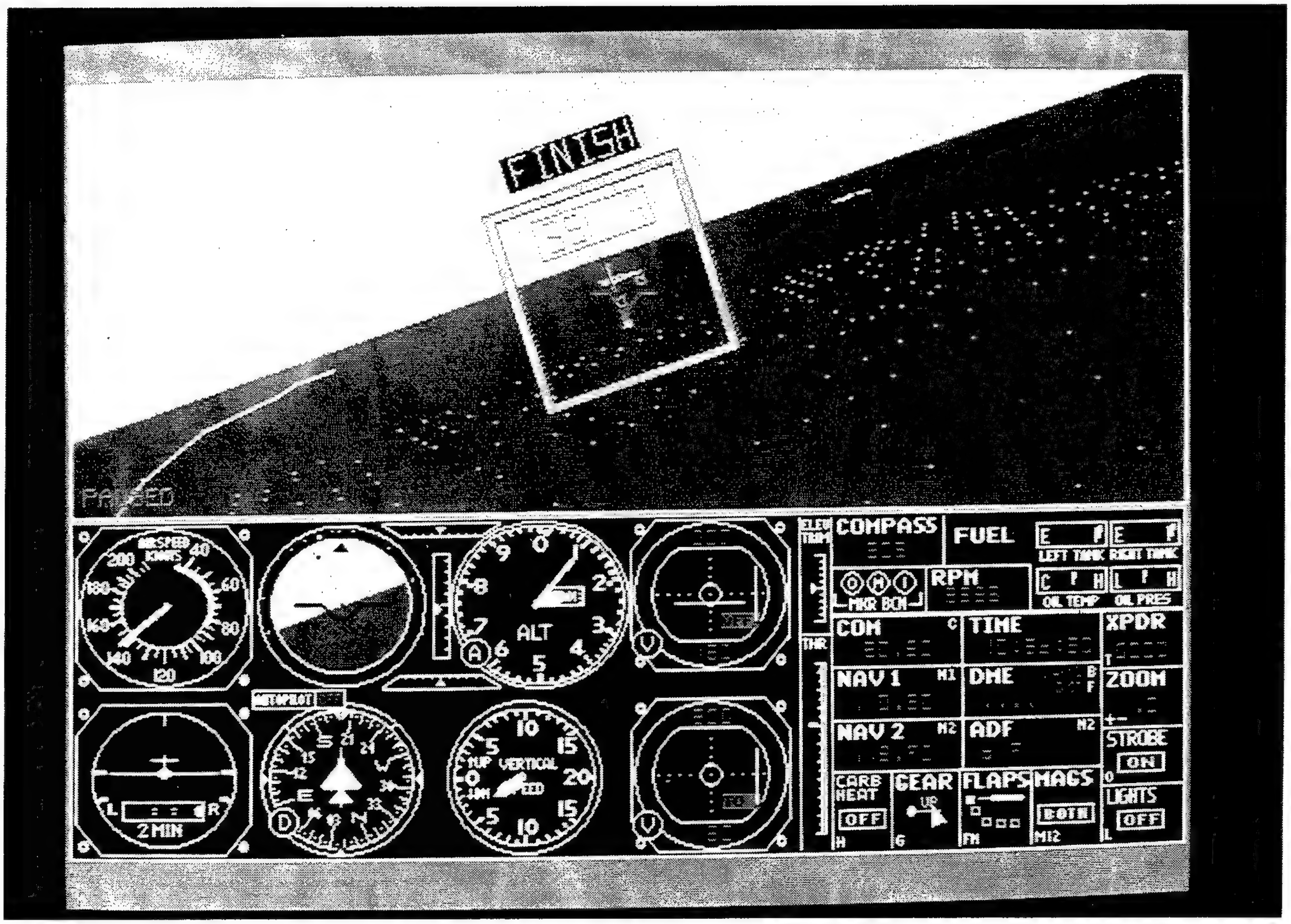

Figure 4. The DTFS screen just prior to crossing finish gate.

Procedure

On Monday (training day), subjects received a brief orientation to the flight simulator 4.0® program and were given a 10-minute flight lesson to familiarize them with the take-off and flight characteristics of the simulated aircraft. Then, the subjects completed one iteration of the flight profile under the guidance of a staff member. Flights 2 and 3 on Monday were also training flights and assistance was provided as needed. Beginning Tuesday, all sessions were considered data collection flights.

Experimental setup

The task was conducted in a testing room illuminated by a small desk lamp. The control yoke was clamped to the computer table, and the mouse was located on a small table positioned according to subject preference. The subject sat in a comfortable, height-adjustable chair (figure 5). Audio intercom and video cables ran through a port to the monitoring station outside the room.

The DTFS computer screen and the subject's face were monitored by research staff via CRTs outside the testing room and recorded on videotape (figure 6). This facilitated real time assessment of subject alertness and post flight score analysis.

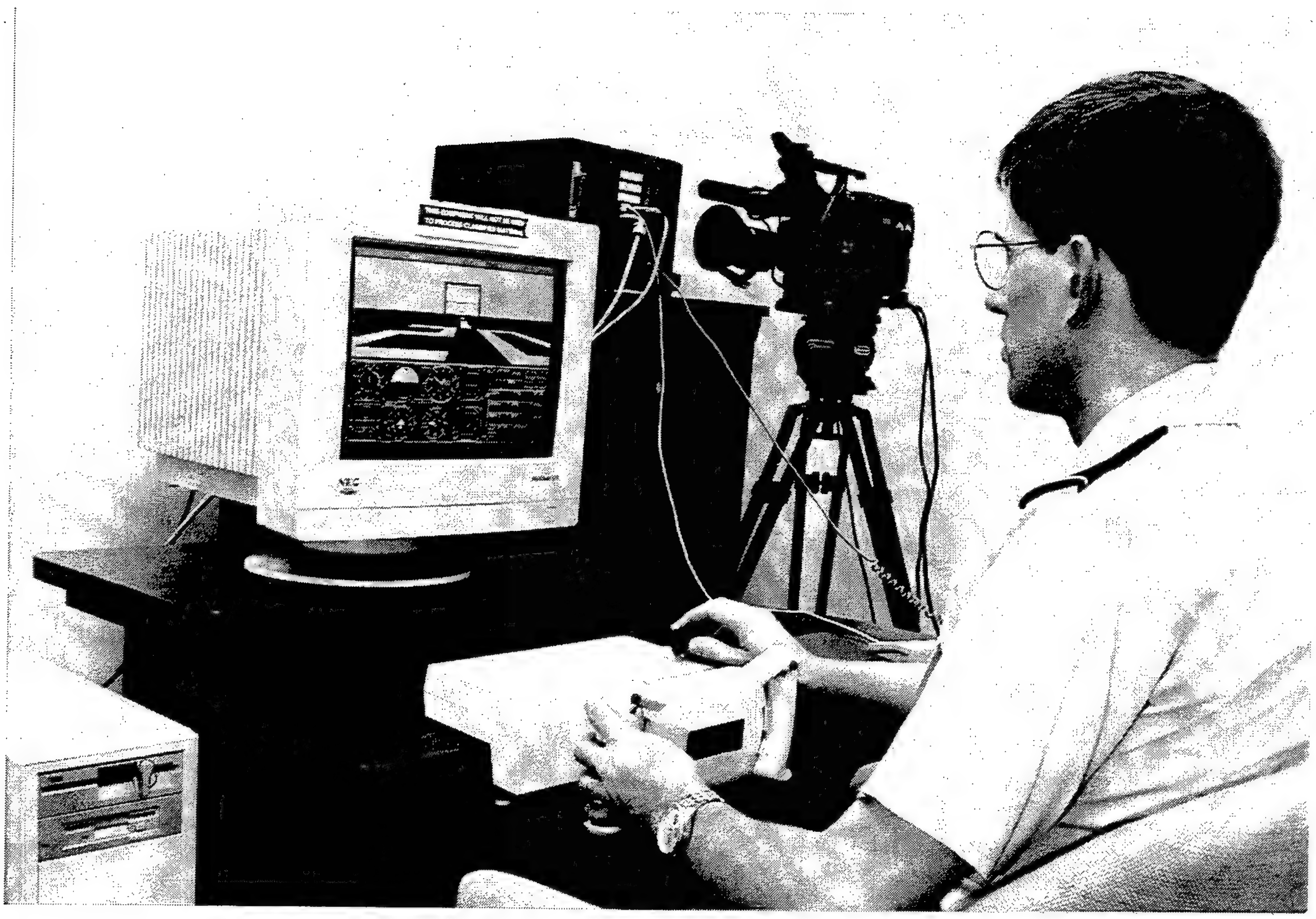

Figure 5. The experimental setup.

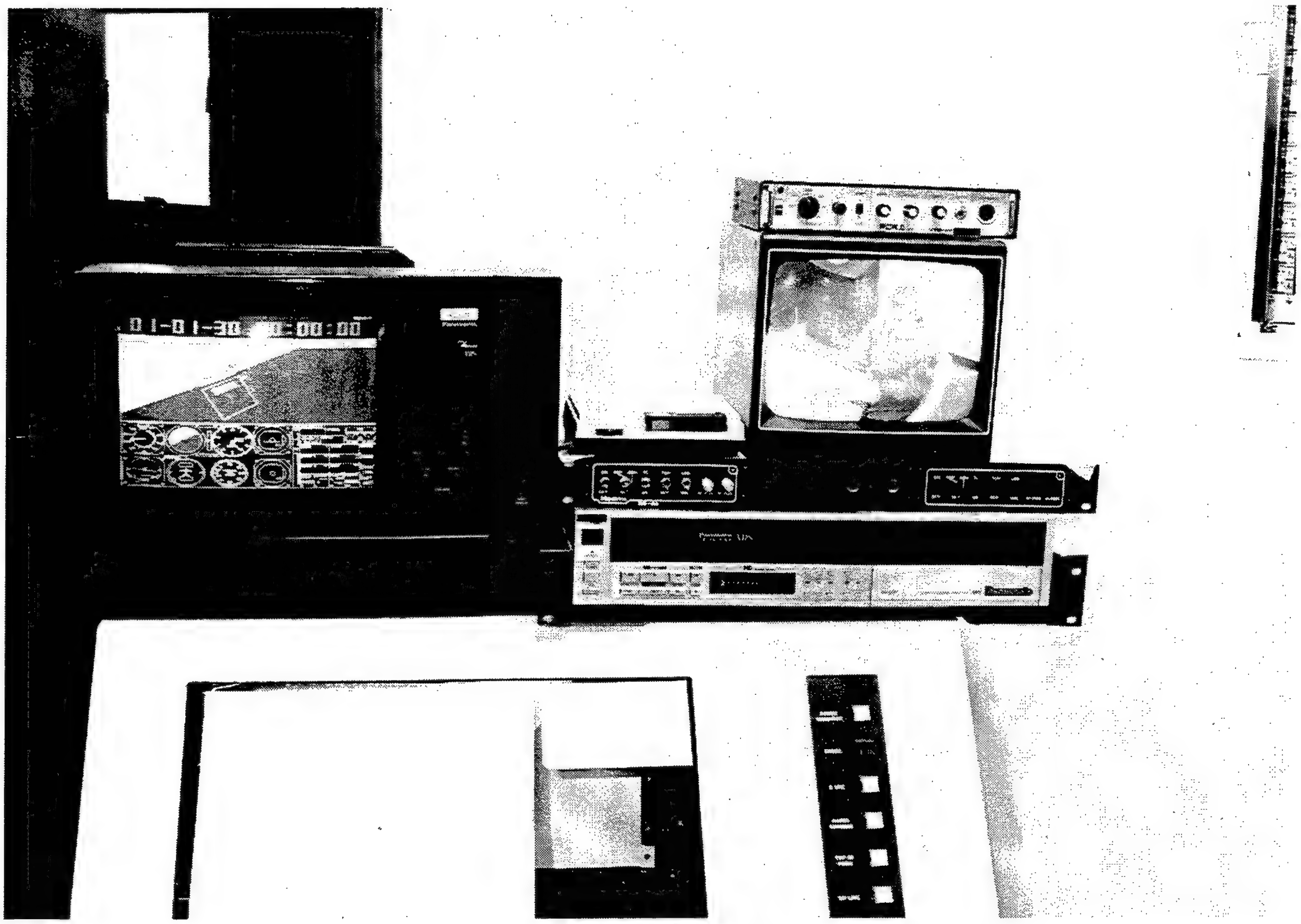

Figure 6. The subject's face and the computer screen were monitored outside the testing room.

Dependent measures

The principal DTFS variable of interest was the summary score, which was calculated automatically from the elapsed time, number of gates missed, and precision in flying through the center of each gate. The summary score, average speed, and elapsed time were calculated and displayed by the FS4.0® program after the subject passed through the finish gate. These were saved to computer disk and also recorded manually by the research technician.

In the secondary task (used in experiment 2 only), reaction time and correctness of response (i.e., high or low tone responses) were recorded. Subsequent data processing resulted in the following performance measures: number of erroneous button presses (errors of commission), number of missed responses (errors of omission), overall reaction time, and reaction time for correct responses. These results were also stratified into windy/non-windy levels of difficulty.

Analysis

Data were analyzed with BMDP 4V repeated measures analysis of variance (ANOVA) (Dixon et al., 1990) using the two within-subject factors of drug (placebo, Dexedrine) and session (0300, 0700, 1100, 1500, and 1900). Significant main effects were followed by appropriate post hoc statistics.

Experiment 1: Male helicopter pilots and dextroamphetamine

Methods

Six UH-60 qualified male aviators participated in this study in which the DTFS was employed as a single task.

Results

Subjects generally reached asymptotic performance on the DTFS within four sessions (figure 7), although there was intrasubject variability after this point (figure 8). In figure 7, the curved lines represent second order regressions. Note that in figures 7 and 8, subjects were sleep deprived and under the influence of drug or placebo during the sessions on day 3.

Analysis of the summary scores revealed no main effects, but there was an interaction between drug and session ($F(2.34, 11.72)=4.26$, $p=0.0361$). Although corrections for sphericity violations yielded nonsignificant simple effects, the interactions tended to be due to an overall difference among the various sessions at placebo ($p<0.12$) but not Dexedrine. Subsequent contrasts revealed that performance at placebo was significantly better at 1900 than at either 1100 or 1500. While performance at 0700 also appears to be worse than 0300 and 1900 (figure 9), the difference was not significant.

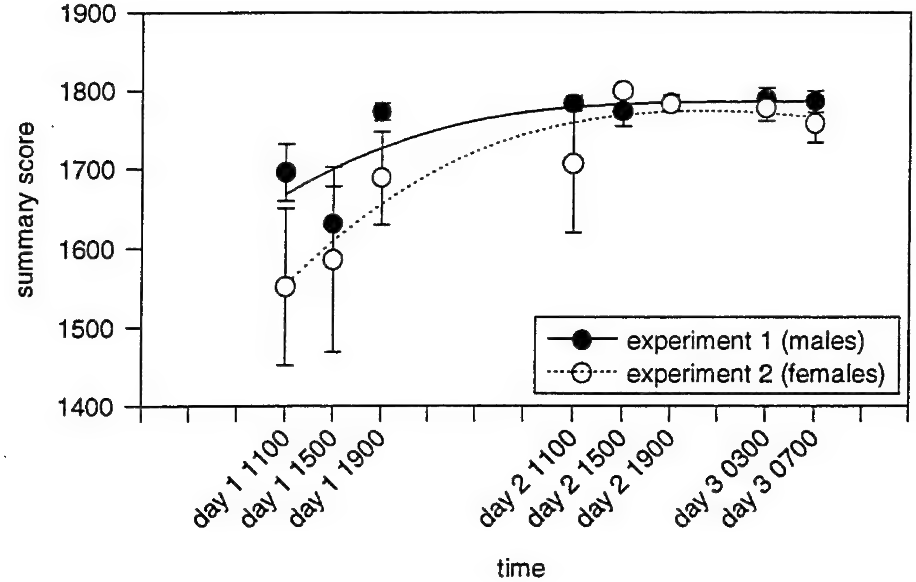

Figure 7. Performance during training sessions for experiments 1 (males) and 2 (females).

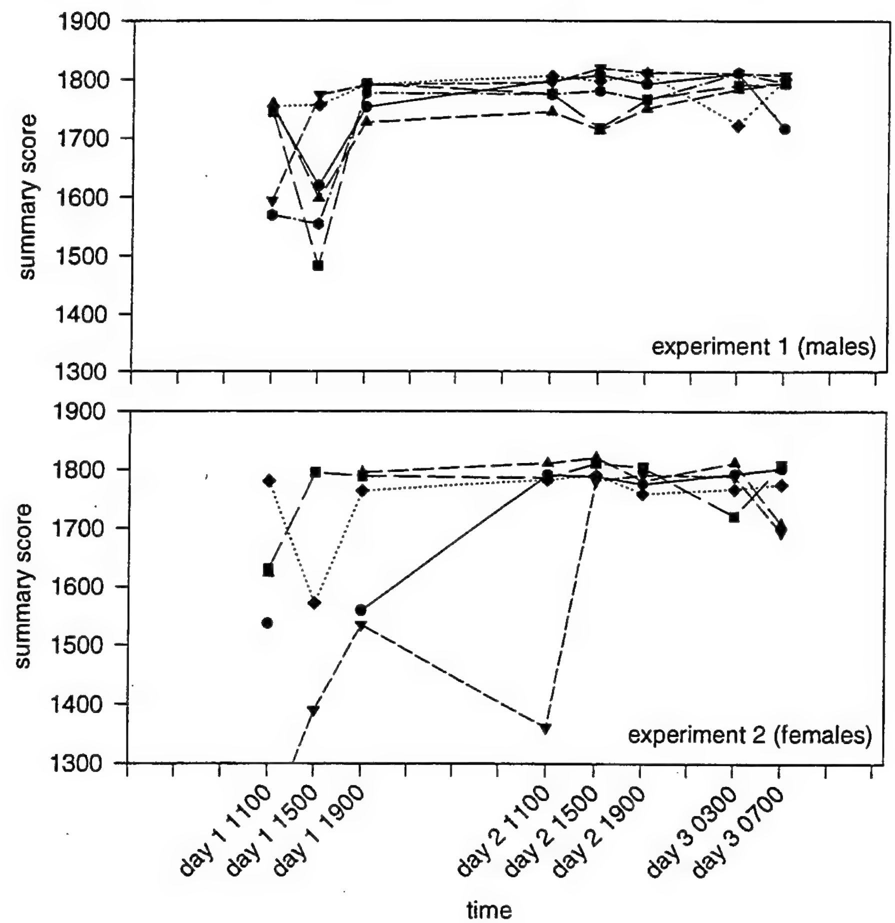

Figure 8. Individual plots of summary score performance during training sessions for experiments 1 (males) and 2 (females).

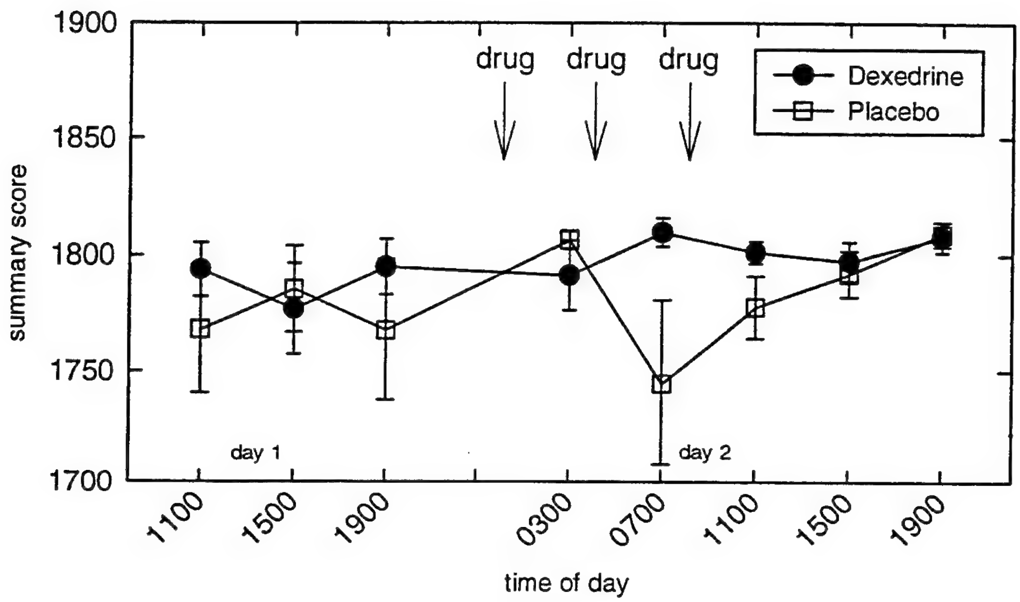

Figure 9. Experiment 1: DTFS summary score for six male subjects.

Experiment 2: Female helicopter pilots and dextroamphetamine

Methods

Six UH-60 qualified female aviators participated in this study, in which the DTFS served as the primary task, and the auditory reaction time task served as a secondary task.

The training process for experiment 2 was identical to the previous study except that subjects received additional training on the reaction time task after initial flight training. Subjects practiced the task by itself, then in combination with the flight task. Similarly, data collection procedures were identical to those employed in experiment 1 with the addition of the reaction time secondary task.

Results

As the secondary task was significantly modified after the first subject completed the study, only five subjects contributed data to this analysis. Two of the five had missing reaction time data for one session; these were estimated using means of existing data.

Subjects generally reached asymptotic performance on the DTFS by the fifth session (figure 7), although there was considerable inter-subject variability (figure 8).

Although there appeared to be differences between drug and placebo for the DTFS summary score (figure 10), there were no significant drug main effects or drug-by-session interactions. Similarly, there were no significant effects for reaction time (overall, low and high turbulence) or the number of high/low errors on the secondary task. There were significant session effects on overall reaction time ($F(4,16)=4.77$, $p=0.01$). Subsequent analysis of contrasts revealed that the overall reaction time effect was due to slower reaction time at 0700 than at 0300 and 1500, and slower at 1100 than at 1500 ($p<0.05$). In the nonwindy segments, reaction time was slower at 0700 and 1100 than at 0300 ($p<0.05$).

Although reaction time variables did not achieve statistical significance, note that mean reaction times were consistently in the expected direction (figure 11). Similarly, while the overall ANOVA for low-tone errors (errors of omission) revealed no effects, the difference between drug groups at 0700 approached significance (paired t-test, $p=0.075$)(figure 12). These observations should be interpreted carefully in view of the small sample size and large inter- and intra-subject variability.

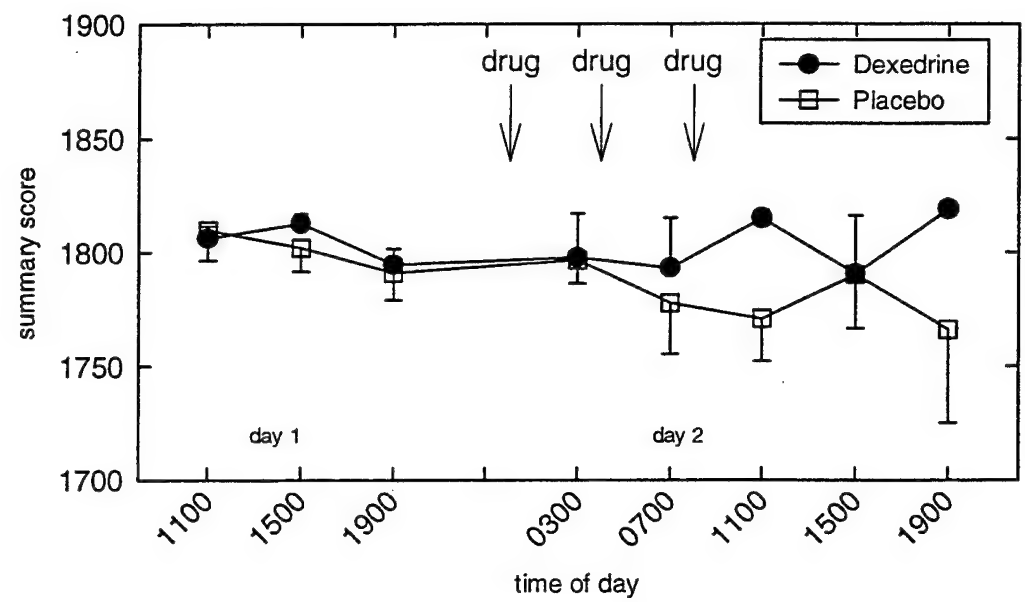

Figure 10. Experiment 2: DTFS summary score for five female subjects.

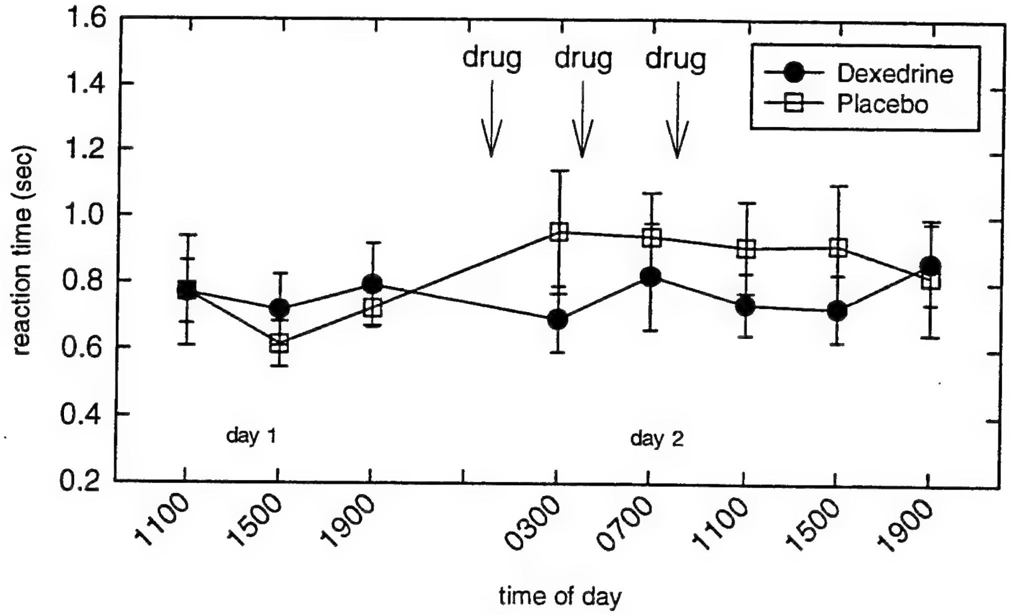

Figure 11. Mean reaction time for the auditory reaction time secondary task.

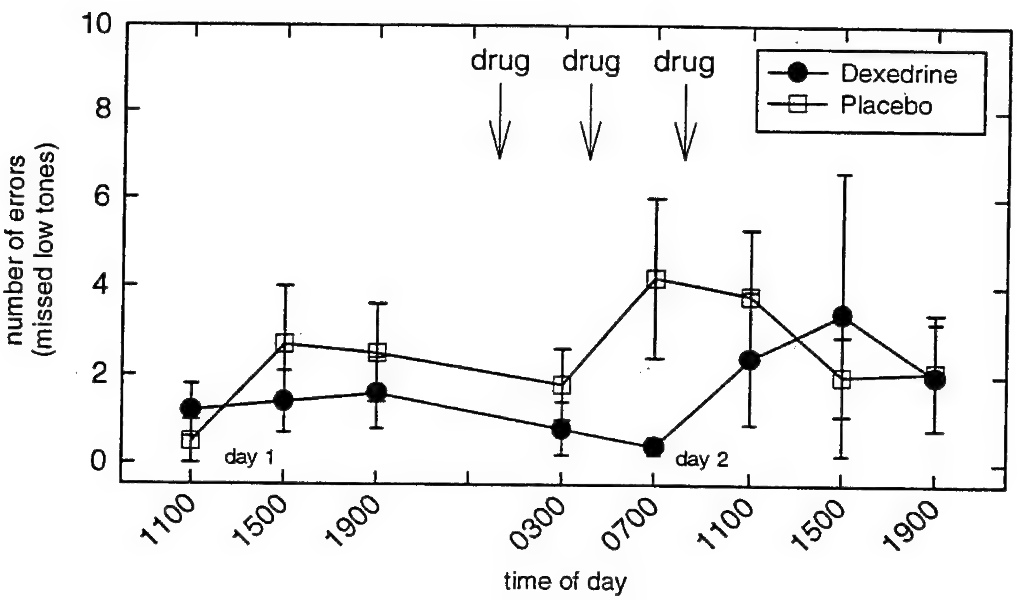

Figure 12. Mean number of low tone errors (errors of omission)
for the auditory reaction time secondary task.

Discussion

Microcomputer-based flight simulation

Modern microcomputers, or PCs, have revolutionized everyday life. In flight simulation, these powerful compact units have many advantages over their bulky ancestors, not the least of which are cost, portability, and accessibility. Flight simulation software, mostly intended for game enthusiasts, has been available for the desktop computer for years. In fact, computer processors now considered obsolete are capable of running reasonably high fidelity flight simulation programs (Benton et al., 1992). It is true that cutting edge graphics, flight models, and motion systems require immense computational power that only can be provided by large mainframe computers, but PCs are ideally suited to some types of operational flight performance measurement.

There is precedent for the use of microcomputers in aviation performance research. Beringer (1994) designed a research flight simulation package that combined an instrument training program with the graphics from a recreational flight simulation. Preliminary results from a study comparing two instrument display formats suggest that this simulation was sensitive to changes in instrument flight and procedural errors.

Moroney has been using Microsoft Flight Simulator 4.0®* as a research and human factors training tool for several years (Moroney and Moroney, 1991). Microsoft's Aircraft and Scenery Designer®* was used to create a flying course in the same manner employed in the present investigation, although Moroney's course consisted of 12 gates arranged in a straight line, all at the same altitude. Difficulty was varied by incrementally increasing crosswind. Butkus, Hughes, and Moroney (1992) combined this task with a data entry task in a successful comparison of miniaturized keyboards intended for aircraft use. The summary score, automatically generated by the FS 4.0® program, was used as a primary dependent variable in two studies examining various scoring strategies for a workload task (Moroney et al., 1992; Moroney et al., 1993).

Using FS 4.0® in a different manner, Thornton studied the effect of automation in the cockpit (Thornton et al., 1992). In two-person crews, subjects flew simulated disaster relief missions that involved mission planning, navigation, and flight performance measures. It is unclear how the flight performance measures (i.e., altitude and course deviation) were obtained, since these are not automatically generated by the FS 4.0® program. Four-choice reaction time served as a secondary task throughout the flight. Differences were found in altitude deviation, subjective workload, and reaction time, depending on the level of automation.

For the present study, a longer and more complex flight course than Moroney's was designed in order to increase the likelihood of detecting fatigue-related performance decrements. This represents the first opportunity to compare a FS 4.0® task to other measures of aviator performance as UH-60 flight simulator data were simultaneously gathered.

The DTFS as a test

According to Turnage et al. (1992), a new measure of human performance should possess the metric qualities of stability, reliability, validity, and sensitivity. Further, the ideal computerized performance test battery should have the following five practical qualities: portability, self-administered, self-scoring, no special interfaces required, and minimal administration time (<15 minutes). While it was not the purpose of this investigation to systematically prove or disprove the benefit of the DTFS, most of these criteria can be at least partially addressed.

Most subjects required between three to five test sessions to reach the point of differential *stability* on the DTFS task (figure 7). As a group, females appeared to take slightly longer than males to plateau; however, this may have been due to the secondary task (used only in experiment 2). Retest *reliability* was not calculated, since subjects began sleep deprivation after six test sessions regardless of DTFS performance. However, figure 8 shows that a degree of intra-subject variability did persist. The DTFS task has inherent external *validity* with regard to basic flight skills, but is based on a light fixed wing civil aircraft. This would limit applicability to military flying, especially the rotary-wing environment; nonetheless, cruise flight in helicopters and light fixed wing aircraft is basically the same flight task.

The two studies of Dexedrine and helicopter pilots that served as the testbed for the DTFS provided an ideal opportunity to evaluate the novel task's *sensitivity* to acute fatigue. These studies also enabled the comparison of DTFS performance with a "gold standard" -- the UH-60 helicopter simulator. Figure 13 compares performance on the DTFS with performance on the UH-60 simulator. These figures should be interpreted with caution, as they were scaled primarily for ease of presentation, not direct comparison. Nonetheless, it is apparent that the DTFS generally mirrored the results obtained in the UH-60 flight simulator, although analysis showed that the effect was weaker and did not achieve the same level of statistical significance.

As a stand-alone task in experiment 1, the DTFS detected statistically significant performance changes over time in the placebo condition that were not seen after Dexedrine administration. Even so, it was apparent to the research staff that the task did not consistently reflect the severe fatigue experienced by most subjects. For example, subjects frequently "nodded off" during the longer flight segments, but recovered in time to achieve a good score as they passed through the next gate. In experiment 2, the auditory reaction time secondary task was added as an attempt to measure performance and alertness throughout the flight. While no significant results were obtained, there were trends in the expected direction (figures 10, 11, and 12). The UH-60 data also revealed a less dramatic effect of Dexedrine in females than in males, but a consistent and statistically significant result was still obtained (Caldwell et al., 1995). Subjectively, the female subjects that were tested in experiment 2 seemed more resistant to the effects of sleep deprivation than the male subjects in experiment 1. The small number of subjects available for analysis in experiment 2 (n=5) further reduced the likelihood of a significant result in the DTFS task.

The DTFS also can be evaluated in terms of the five practical properties cited by Turnage et al. (1992). It certainly is *portable*, requiring only a computer, a screen, and a power supply. In fact, the task has been successfully used in flight recently, employing a laptop computer and color liquid crystal display (LCD). The DTFS could easily be *self-administered*, although this was not done in the present studies. Currently, the task is *self-scoring* with respect to the FS 4.0® summary score, but the reaction time secondary task requires manual data manipulation. There is a requirement for *additional special interface* equipment, in that a flight yoke is strongly recommended. However, the task can be flown using a mouse, trackball, or the keyboard (although this would challenge the validity of the task). Finally, Turnage et al. (1992) recommended a test duration of less than 15 minutes. The DTFS, in the configuration used in these studies, takes about 25 minutes to complete. However, the DTFS was specifically designed to detect fatigue- or drug-related performance decrements, and long, monotonous stretches of straight-and-level flying are desirable in this context.

The future of the DTFS

Although the DTFS did not consistently reveal a statistically overpowering effect of fatigue on FS 4.0® performance, definite trends were obtained. At the present time, the DTFS should not be used as the sole measure of aviator performance, but it could serve as an important part of many studies. Its advantages of portability, low cost, and subject acceptance have seen it included (in its present form) in an in-flight study of aircrew fatigue. A longer version of the task (45 minutes vs 25 minutes) is also being used in a deployment study of circadian desynchronosis.

Potential enhancements to the DTFS could include: a) operational mission scenario(s) suitable for a light fixed wing aircraft (e.g., medical evacuation, reconnaissance; see Thornton, et al., 1992); b) more specific mission-related performance measures such as fuel calculations (Gawron, Knotts, and Schiflett, 1989); c) helicopter cockpit graphics and/or flight characteristics; d) capture of flight performance parameters (e.g., altitude, airspeed, etc.,); and e) projection of out-the-window graphics to provide a more compelling visual scene.

In the end, individual investigators must weigh the limitations of this low-fidelity flight simulation against the practical constraints on aviation human factors research involving actual aircraft or full mission simulators. Tasks such as the DTFS may allow the inclusion of a measure of flying skill, however crude, in under funded studies that otherwise would have limited relevance to the aviation environment.

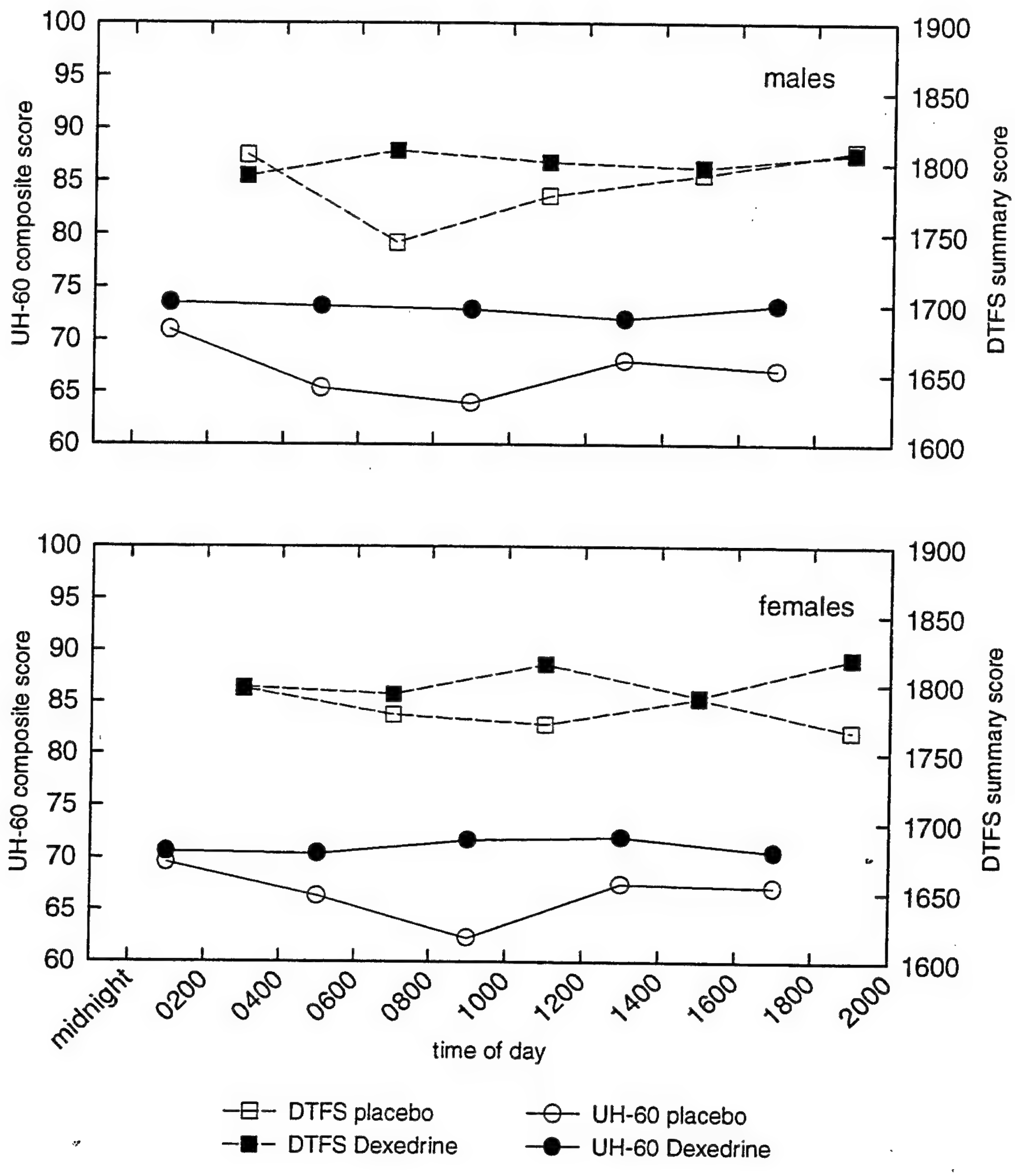

Figure 13. Comparison of flight performance data from the DTFS and the UH-60 flight simulator for males (top) and females (bottom).

References

Benton, C., Corriveau, P., Koonce, J., and Tirre, W. 1992. Development of the basic flight instruction tutoring system (BFITS). Brooks Air Force Base, Texas: Armstrong Laboratory. AL-TP-1991-0060.

Beringer, D. 1994. Issues in using off-the-shelf PC-based flight simulation for research and training: Historical perspective, current solutions, and emerging technologies. In: Proceedings of the Human Factors Society 38th Annual Meeting. 90-94.

Butkus, K., Hughes, E., and Moroney, W. 1992. An evaluation of miniaturized aircraft keyboards. In: Proceedings of the National Aerospace Electronics Conference. 698-704.

Caldwell, J.A., Caldwell, J.L., Crowley, J.S., Jones, H.D., Darling, S.R., Wallace, S.L., Woodrum, L.C., and Colon, J.A. 1994. Effects of dextroamphetamine on helicopter pilot performance: A UH-60 simulator study. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Report No. 94-43.

Caldwell, J., Crowley, J., Caldwell, L., Jones, H.D., Darling, S., Wallace, S., and Pegues, A. 1995. Sustaining female UH-60 helicopter pilot performance with Dexedrine during sustained operations: A simulator study. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Report No. 95-27.

Dixon, W., Brown, M., Engelman, L., and Jenrich, R. (eds). 1990. BMDP statistical software manual. Berkeley, CA: University of California Press.

Gawron, V., Knotts, L., and Schiflett, S. 1989. Mapping laboratory tests to in-flight tasks. Flight Simulation Technologies Conference and Exhibit, Boston, MA, Aug 14-16, 1989. American Institute of Aeronautics and Astronautics, Technical Paper A89-48376 21-09. 462-469.

Moroney, W., Biers, D., Eggemeier, T., and Mitchell, J. 1992. Comparison of two scoring procedures with the NASA Task Load Index in a simulated flight task. In: Proceedings of the National Aerospace Electronics Conference. 734-740.

Moroney, W., and Moroney, B. 1991. Utilizing a microcomputer-based flight simulation in teaching human factors in aviation. In: Proceedings of the Human Factors Society 35th Annual Meeting. 523-528.

Moroney, W., Reising, J., Biers, D., and Eggemeier, F. 1993. The effect of previous workload on the NASA Task Load Index (TLX) in a simulated flight task. In: Proceedings of the Seventh International Symposium on Aviation Psychology. Vol 3. Columbus, OH: Ohio State University. 882-885.

Thornton, C., Braun, C., Bowers, C., and Morgan, B. 1992. Automation effects in the cockpit: a low fidelity investigation. In: Proceedings of the Human Factors Society 36th Annual Meeting. 30-34.

Turnage, J., Kennedy, R., Smith, M., Baltzley, D., and Lane, N. 1992. Development of microcomputer-based mental acuity tests. Ergonomics. 35:1271-1295.

Appendix A.

Manufacturer's list

Microsoft
1 Microsoft Way
Redmond, WA 98052

CH Products
970 Park Center Drive
Vista, CA 92083

Coulbourn Instruments
Box 2551
Lehigh Valley, PA 18001

Appendix B.
Location of DTFS gates

Gate #	Center Altitude (ft agl)	Center Altitude (ft msl)	North*	East*	Heading (deg)
0	52	603	17066.7969	16614.2500	202.29
1	200	754	17061.9922	16612.2188	203.35
2	501	1056	17057.6719	16609.1875	225.36
3	1502	2236	17033.0938	16591.6368	215.47
4	2059	2794	17029.1094	16586.9844	247.63
5	1502	2237	17028.8868	16579.6133	275.33
6	951	1685	17025.6563	16571.7930	231.19
7	501	1234	17021.9375	16567.1719	231.11
8	3001	3735	17022.8321	16525.9610	273.14
9	3001	3571	17035.1094	16510.1758	315.05
10	3001	3571	17040.1875	16507.9414	346.04
11	2502	3073	17050.0000	16502.0039	326.63
12	4001	4572	17072.0430	16497.9766	332.98
13	2502	3164	17076.6914	16498.1211	012.36
14	3001	3663	17101.0118	16500.2032	351.17
15	3801	4462	17109.0430	16509.7579	063.30
16	4300	4959	17106.0782	16522.8594	129.79
17	4601	5264	17095.3907	16538.9336	123.40
18	4801	5464	17092.4336	16540.6680	179.01
19	4601	5264	17081.6836	16542.6133	161.24
20	4601	5264	17077.3438	16558.8125	097.74
21	4300	4962	17078.4883	16569.5157	069.63
22	701	1256	17086.6016	16591.3750	069.63

* Microsoft Flight Simulator® coordinate system.

Appendix C.

Instructions for subjects in experiments 1 and 2

This flight profile will assess your ability to fly a simulated Cessna Skylane through a course that is approximately 25 minutes long. Your objective will be to fly the most direct and fastest route through a total of 21 gates positioned at various altitudes and headings. After completion of the course, your performance will be calculated from the elapsed time it takes to fly the course, the number of gates missed, and the precision with which you fly through each gate.

Your objective throughout the course is to fly as fast as possible through a total of twenty-one gates. When planning your approach to a gate, try to pass through the crosshairs located at the center of the gate. It is important that you pass through the gate as close as possible to the crosshairs. At times it may be difficult to find the next gate if you don't plan well. The next gate will always flicker or blink to help you identify it, but this may be difficult to see if it is far away. It is best to look ahead one or two gates, especially during your training today.

It is also important that you do not miss any gates throughout the course. If you should miss a gate, it is best to circle around and attempt your maneuver again. To successfully do this, you must be aware of the different colors of the gate and their meaning. The front of the gates are colored green, so a green gate indicates that you are approaching the gate from the correct direction. A red gate indicates that you are approaching the gate from the back--the wrong direction. Finally, a gray gate is used to show a gate which you have already passed through.

At certain points throughout the course, you will experience turbulence--a shaking of the visual scene. Try to remain as straight as possible when this occurs and go on through the gates.

There are several devices and instruments with which you should be familiar. [Note: point out each device as you speak.] The yoke is your means of controlling the aircraft. The throttle controls the velocity at which you travel, and will only be manipulated during initial takeoff. There are also two trim adjusters. We preset these so that you do not have an easy flight. The airspeed dial shows the speed at which you are traveling. If you fall below 60 knots, you will begin to stall, and a stall indicator will flash on the lower right-hand side of the screen. To recover from a stall, nose dive until you regain speed; then slowly regain your altitude. The gear indicator tells you the positioning of the landing gear. After takeoff, the gear should be in the up position. You will change the positioning of the gear by pressing "G" after going through the start gate. If you do not raise your landing gear, your overall speed will be significantly lowered.

You will begin the flight by pressing "P" to unpause the simulator screen. After pressing "P," briefly press the brakes (the red buttons located on the right and left side of the yoke) to stop any aircraft movement. After one minute, when the clock time reaches 1200, push the throttle all the

way forward. Leave the throttle in this position throughout the flight. Proceed through the start gate, and at approximately 60 knots, take off by slowly pulling back on the yoke and fly toward gate #1. Before reaching gate #1, press "G" to raise the landing gear. Then continue on flying through the remaining 20 gates.

If you crash, press "P" to pause the simulator screen and someone will be in to assist you. If at any time you need assistance (for example, if you crash, get disoriented, or have a question), just press the intercom and someone will be in to help you. We will be watching you on a monitor outside the room, so we can usually tell if you need assistance.

At the end of the course, you will pass through the finish gate. At this point, a score screen will appear, and someone will be in to help you.

Appendix D.

Additional instructions for subjects in experiment 2 only

After this first training flight, you will be presented with an auditory task. Throughout the course, you will hear a series of auditory tones which will consist of either a high or low frequency. When the low frequency tone is heard, immediately press the right brake button. (Note: give the subject an example of each tone.) It is only on your first training flight that the auditory task will not be present.